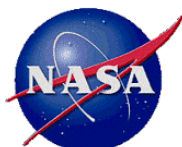


**FINAL  
GROUNDWATER  
MONITORING REPORT  
APRIL - MAY 2004**



**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
JET PROPULSION LABORATORY  
4800 Oak Grove Drive  
Pasadena, California 91109**

**Contract No. N68711-01-D-6008**

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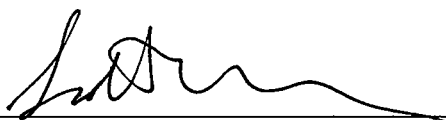
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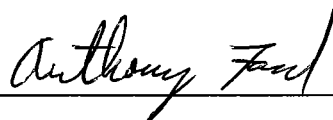
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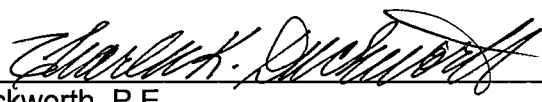
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## ACRONYMS/ABBREVIATIONS

1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethene
APCL	Applied Physics and Chemistry Laboratory
As	total arsenic
CCl <sub>4</sub>	carbon tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
ClO <sub>4</sub> <sup>-</sup>	perchlorate
Cr	total chromium
Cr(VI)	hexavalent chromium
DHS	California Department of Health Services
DLR	detection level for the purpose of reporting
DQOs	data quality objectives
DTSC	Department of Toxic Substance Control
EPA	United States Environmental Protection Agency
GEOFON	GEOFON Incorporated
IAL	State Interim Action Level
JPL	Jet Propulsion Laboratory
LAWC	Lincoln Avenue Water Company
LCID	La Canada Irrigation District
LDC	Laboratory Data Consultants, Inc.
LFWC	Las Flores Water Company
MCLs	Maximum Contaminant Levels
µg/L	micrograms per liter
mg/L	milligrams per liter
MIBK	4-methyl-2-pentanone
mL	milliliter
MS	matrix spikes
MSD	matrix spike duplicates
MW	monitoring well
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
OU	operable unit
Pb	total lead
PCE	tetrachloroethene
PQL	practical quantitation limit



### **ACRONYMS/ABBREVIATIONS (CONT'D)**

QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RCLWC	Rubio Canon Land & Water Company
RWQCB	California Regional Water Quality Control Board
SOTA	SOTA Environmental Technology, Inc.
TCE	trichloroethene
TDS	total dissolved solids
VOCs	volatile organic compounds
VWC	Valley Water Company
Westbay	Westbay Instruments, Inc.

## EXECUTIVE SUMMARY

Presented in this report are the results of the April - May 2004 groundwater sampling event completed as part of the long-term groundwater monitoring program at the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) under contract with Naval Facilities Engineering Command. This sampling event was conducted from April 26 through May 27, 2004.

During the April - May 2004 quarterly sampling event, groundwater samples were collected from 23 JPL monitoring wells, both on- and off-facility, and analyzed for volatile organic compounds (VOCs), metals, N-nitrosodimethylamine (NDMA), and perchlorate. MW-2 has not been sampled since it was replaced with well MW-14 as a JPL sampling location.

All laboratory analytical data collected were subject to data validation pursuant to the Navy's Level IV quality assurance requirements. Some of the analytical data were qualified based on data validation reviews in accordance with applicable United States Environmental Protection Agency (EPA) guidelines. No data were rejected for non-compliance with method requirements during the course of validation and no data were qualified as unusable. The analytical results are summarized below.

- Seven on-facility wells and three off-facility wells contained concentrations of one or more of four VOCs (carbon tetrachloride, trichloroethene, tetrachloroethene, and 1,1-dichloroethene) that exceeded State or Federal Maximum Contaminant Levels (MCLs) for drinking water. Concentration contour maps generally indicate slow migration of the contaminant plumes over the last year.
- Perchlorate was detected in nine on-facility wells and four off-facility wells, with concentrations in seven on-facility and two off-facility wells that exceeded the State Interim Action Level (IAL).
- Total chromium was detected in all 23 wells sampled; however, none of the concentrations exceeded the State or Federal MCL. Hexavalent chromium [Cr(VI)] was detected at estimated trace concentrations in five on-facility wells. As of January 6, 2004, Cr(VI) is regulated under the 0.050 mg/L MCL for total chromium. The California Department of Health Services (DHS) will be adopting an MCL that is specific for hexavalent chromium at a later date (DHS, 2004a).
- Arsenic was detected in three wells at trace, estimated concentrations below the State and Federal MCLs, and lead was detected above the State IAL only in well MW-17 (Screen 5).
- 1,4-Dioxane was detected above the State IAL in three on-site wells, and NDMA was detected in only one on-site well below State IAL. At this time, neither State nor Federal MCLs have been established for 1,4-dioxane and NDMA.

Groundwater gradients and flow directions before and after sampling activities were consistent with the results from the February 2004 sampling event observations. The natural seasonal fluctuation of the hydraulic head is believed to be the main factor contributing to the difference in water level elevations between each quarterly sampling event. Other factors that might

influence the water level can be caused by several hydrologic phenomena operating simultaneously including, but not limited to, extraction and/or artificial recharge.

## 1.0 INTRODUCTION

The locations of the JPL groundwater monitoring wells are shown on Figure 1-1. Monitoring wells MW-3, MW-4, MW-11, MW-12, MW-14, and MW-17 through MW-24 are deep multi-port wells, each containing five screened intervals equipped with a Westbay Instruments, Inc. (Westbay) multi-port casing system. Monitoring wells MW-1, MW-5 through MW-10, MW-13, MW-15, and MW-16 are relatively shallow standpipe wells, each containing a single screened interval located just below the water table. A summary of the well construction details for the JPL groundwater monitoring wells is included in Table 1-1.

During the April-May 2004 event, GEOFON, Incorporated (GEOFON) personnel collected samples from all JPL monitoring wells except MW-2. Shallow well MW-2 has not been sampled since it was replaced with deep multi-port well MW-14 as a JPL sampling location. Groundwater samples were collected and analyzed in accordance with the sampling program that was previously approved by the Environmental Protection Agency (EPA), Department of Toxic Substance Control (DTSC), and California Regional Water Quality Control Board (RWQCB).

In addition, the water-level elevation at each well was measured on April 26 & 29, 2004 (prior to sampling), and on May 26 & 27, 2004 (after sampling) to evaluate groundwater flow directions and gradients.

All of the JPL groundwater samples were shipped to Applied Physics and Chemistry Laboratory (APCL) in Chino, California, for chemical analysis. APCL is certified by the California Department of Health Services and approved for use by the Naval Facilities Engineering Command, Quality Assurance/Quality Control (QA/QC) program. Sample collection procedures and sample analysis were conducted by GEOFON in accordance with the Work Plan for Performing a Remedial Investigation/Feasibility Study (Ebasco, 1993a), which was approved by the regulatory agencies.

In addition to groundwater samples, field QA/QC samples, including trip blanks, equipment blanks, duplicate samples, and a field blank, were collected for laboratory analyses. Sampling records for each shallow well and field data sheets for deep multi-port wells are included in Appendix A. Piezometric pressure profiling records for each deep multi-port well are included in Appendix B. Laboratory analytical reports and associated chain-of-custody forms are included in Appendix C, and data validation reports are provided in Appendix D.

Appendices E and F present summaries of analytical results for volatile organic compounds (VOCs) and metals, respectively, that were reported by others prior to GEOFON's initiation of the Long-Term Groundwater Monitoring activities at the JPL facility in January of 2003.

Pursuant to the Navy's request, the format of the tables summarizing the results of the groundwater sampling was modified by GEOFON to present the data qualifiers as reported by the company performing data validation.

## **2.0 FIELD SAMPLING PROCEDURES**

Two different procedures were used to collect groundwater samples at JPL, one designed for the shallow wells and the other for the deep multi-port wells. These procedures are outlined below.

### **2.1 Shallow Monitoring Wells**

The sampling procedure described below was applied to all the shallow JPL monitoring wells, including MW-1, MW-5, MW-6, MW-7, MW-8, MW-9, MW-10, MW-13, MW-15 and MW-16.

- The primary equipment used to sample the shallow wells included dedicated 2-inch diameter Grundfos Redi-Flo2® pumps, a pump controller, and a 220-volt generator. All of the dedicated Grundfos Redi-Flo2® pump systems were previously decontaminated prior to their permanent installation. Details of the decontamination procedures for the Grundfos Redi-Flo2® pump systems are outlined in the Operable Unit (OU) OU-1 Field Sampling and Analysis Plan (Ebasco, 1993b).
- Prior to sample collection, the water in each shallow well casing was purged (by pumping between 1.5 and 4 gallons per minute) to remove groundwater that may have been exposed to the atmosphere and thus may not be representative of undisturbed aquifer conditions. This purged groundwater was discharged into 500 or 1,000-gallon polyethylene storage tanks for subsequent disposal by GEOFON in accordance with Federal, State, and local regulations.
- Temperature, pH, electrical conductivity, and turbidity of the water removed from each well were monitored during purging. Pursuant to the approved work plan (Ebasco, 1993b), a minimum of three casing volumes of water was purged and temperature, pH, electrical conductivity and turbidity were monitored for stabilization. When two successive measurements, made approximately 5 minutes apart, were within 10 percent of each other, groundwater samples were collected using the dedicated pump. During sampling for VOCs, the pumping rate was reduced to minimize sample agitation and volatilization. All information concerning sampling was noted on the Groundwater Collection and Sample Log forms included in Appendix A.
- All sample bottles were filled completely without overflowing, capped, labeled, and immediately placed in a cooler with ice. Samples collected for VOCs had zero headspace.

- Calibration, or standardization of the field instruments used to measure temperature, pH, electrical conductivity, and turbidity, was performed according to the manufacturer's specifications at the beginning of each sampling day.

## **2.2 Deep Multi-Port Monitoring Wells**

Sampling of the deep multi-port monitoring wells at JPL required specialized sampling equipment manufactured by Westbay Instruments, Inc. (Westbay). This equipment included a pressure profiling/sampling probe with a surface control unit. To ensure proper use, GEOFON field personnel using this equipment were trained by Westbay personnel. Copies of the detailed operations manuals for the Westbay pressure profiling/sampling probe are included in the OU-1 and OU-3 Field Sampling and Analysis Plans (Ebasco, 1993b; 1994).

The Westbay sampling probe and sample-collection bottles were decontaminated prior to sampling each screened interval in the deep multi-port wells according to the following procedures:

- Each 250-mL stainless-steel sample-collection bottle was washed in a solution of non-phosphate detergent (Liquinox<sup>®</sup>) and distilled water, followed by a solution of an acidic detergent (Citranox<sup>®</sup>) and distilled water.
- Each bottle was rinsed with distilled water.
- The interior surfaces of the Westbay sampling probe, and the hoses and valves associated with the Westbay sample bottles were decontaminated by forcing several volumes of a solution of Liquinox<sup>®</sup> and distilled water through them, followed by several volumes of a solution of Citranox<sup>®</sup> and distilled water. A final rinse with distilled water was then carried out. Each of these decontamination procedures was completed using clean plastic spray bottles for this purpose only.

Purging before sampling was not required in the deep multi-port monitoring wells because the groundwater samples were collected directly from the aquifer, thus ensuring that the groundwater samples were not exposed to the atmosphere. However, at each screened interval, an initial sample was collected in order to check temperature, pH, electrical conductivity, and turbidity in the field. Samples for laboratory analysis were then collected and transferred to sample containers as described in Section 2.1. Results of the field analyses were recorded on groundwater sampling field data sheets (Appendix A). Calibration of field instruments was carried out according to procedures described previously.

### 2.3 Field Quality Assurance/Quality Control Samples

Field QA/QC samples were collected to verify the quality of sampling procedures. The field QA/QC program included the collection of duplicate samples, equipment blanks, trip blanks, and source blanks. Laboratory QA/QC samples were used by the laboratory according to analytical method requirements.

Duplicate samples for VOCs, metals (including hexavalent chromium [Cr(VI)], total chromium (Cr), arsenic, and lead), N-nitrosodimethylamine (NDMA), and/or perchlorate ( $\text{ClO}_4^-$ ) analyses were collected from deep multi-port monitoring wells MW-3 (Screen 1), MW-4 (Screen 2), MW-11 (Screen 3), MW-12 (Screen 4), and MW-22 (Screen 5). Duplicate samples were also collected from shallow wells MW-7 and MW-15.

Matrix-Spike (MS) and Matrix-Spike Duplicate (MSD) samples were collected for 10% of samples that were analyzed for VOCs, metals, and  $\text{ClO}_4^-$ . These samples were used for laboratory QA/QC requirements.

One equipment blank was collected from the Westbay sample-collection bottles during each day of sampling the deep multi-port wells. Equipment blank samples consisted of distilled water that was passed through the sampling equipment after the equipment was decontaminated. Equipment blanks were analyzed for the same constituents as the groundwater samples, except for cations and anions, total dissolved solids, and pH, to identify potential cross contamination due to inadequate decontamination. Because only dedicated sampling equipment was used, equipment blanks were not collected during sampling of the shallow wells.

A trip blank, consisting of American Society for Testing Materials Type II water placed in two 40-mL glass vials by the laboratory, was transported with the empty sample bottles to the field and back to the laboratory with the groundwater samples. One trip blank was submitted for VOC analysis with each shipment of groundwater samples to the laboratory. Trip blanks were used to identify potential cross contamination of groundwater samples during transport.



### 3.0 ANALYTICAL RESULTS

The groundwater samples collected during this sampling event were analyzed for the following:

- Volatile Organic Compounds (VOCs) including 1,4-Dioxane
- Total Chromium (Cr)
- Hexavalent Chromium [Cr(VI)]
- Arsenic
- Lead
- N-nitrosodimethylamine (NDMA)
- Perchlorate ( $\text{ClO}_4^-$ )

A summary of the samples collected and the analyses performed on each sample is presented in Table 3-1. Analytical laboratory reports and associated chain-of-custody forms are included in Appendix C.

The aquifer beneath JPL was divided into four aquifer layers based primarily on correlations interpreted from lithologic cross sections (Foster Wheeler, 2000). Table 3-2 provides a list of the JPL monitoring well screens and their corresponding aquifer layers. Concentration contours of carbon tetrachloride ( $\text{CCl}_4$ ), trichloroethene (TCE), tetrachloroethene (PCE), and perchlorate ( $\text{ClO}_4^-$ ) reported during this event are presented for aquifer layers one, two, and three on Figures 3-1 through 3-12.

#### 3.1 Volatile Organic Compounds

Groundwater samples collected during the April - May 2004 sampling event were analyzed for over 60 different VOCs in accordance with EPA Method 524.2. Results of the analyses for VOCs are summarized in Table 3-3 along with the State and Federal Maximum Contaminant Levels (MCLs) for drinking water as listed in Title 22 of the California Code of Regulations and in the EPA Health Advisory Guidelines.

A small number of compounds were detected in the JPL samples, and four VOCs [ $\text{CCl}_4$ , TCE, PCE and 1,1-dichloroethene (1,1-DCE)] were found in one or more wells at concentrations that exceeded State and/or Federal MCLs. The concentrations of  $\text{CCl}_4$ , TCE, and PCE detected in each aquifer layer were contoured on site maps to show the spatial distribution of each constituent (Figures 3-1 through 3-9). The analytical results for compounds that exceeded MCLs are discussed below.

- Concentrations of  $\text{CCl}_4$  in excess of the State MCL [0.5 micrograms per liter ( $\mu\text{g/L}$ )] were reported in samples from six on-facility wells [MW-3 (Screen 2), MW-7, MW-12 (Screens 3,

4, and 5), MW-13, MW-16, and MW-24 (Screens 1 and 2)] and two off-facility wells [MW-17 (Screen 2), and MW-18 (Screen 4)]. The Federal MCL (5.0 µg/L) was exceeded in MW-7 and MW-24 (Screen 1). The highest concentration of CCl<sub>4</sub> was reported in the duplicate sample (DUPE-7-2Q04) of well MW-7 (65.1 µg/L).

- TCE was detected in ten on-facility wells and four off-facility wells. Reported TCE concentrations exceeded the State and Federal MCL (5.0 µg/L) in three on-facility wells MW-7, MW-10, and MW-13. The highest concentration of TCE was reported in well MW-10 (13.4 µg/L).
- PCE was detected in nine on-facility and three off-facility wells. The State and Federal MCL (5.0 µg/L) was exceeded in on-facility well MW-7 (15.6 µg/L) and off-facility well MW-21 (6.4 µg/L in Screen 5).
- 1,1-DCE was detected in only one on-facility well, MW-7 (7.6 µg/L), at a concentration exceeding the State and Federal MCLs (6.0 µg/L and 7.0 µg/L, respectively).

A summary of the VOC results compiled from the long-term sampling events since January 2003 that have been completed to date is provided in Table 3-4. Nine chemicals have been most commonly reported with concentrations above the laboratory detection limits [CCl<sub>4</sub>, TCE, PCE, 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,1-DCE, Freon 113, chloroform, and ClO<sub>4</sub><sup>-</sup>]. The concentrations of these compounds versus time were plotted, if at any time they exceeded their respective MCL from August/September 1996 through April - May 2004. The plots are presented on Figures 3-13 through 3-63.

Additional data regarding VOC concentrations in samples collected from April 1, 2004 to June 30, 2004 from fourteen municipal production wells in the vicinity of JPL were requested from the California Department of Health Services (DHS) Drinking Water Program. Data was requested from the following purveyors; La Canada Irrigation District (LCID), Lincoln Avenue Water Company (LAWC), Valley Water Company (VWC), Rubio Canon Land & Water Company (RCLWC), and Las Flores Water Company (LFWC). However, according to DHS, only nine of fourteen municipal wells in the vicinity of JPL were sampled for VOCs during the time period requested (DHS, 2004b).

CCl<sub>4</sub> was detected above the State MCL (0.5 µg/L) at LAWC Well #3 (1.0 µg/L) and Well #5 (0.8 µg/L). PCE was detected at concentrations above the State and Federal MCL (5.0 µg/L) at LFWC Well #2 (maximum concentration of 9.3 µg/L). TCE was detected at concentrations above the State and Federal MCL (5.0 µg/L) at LFWC Well #5 (16.0 µg/L). Chloroform was detected in all LAWC and VWC wells that were sampled; however none of the concentrations exceed the State and Federal MCL (100.0 µg/L) (DHS, 2004b). The drinking water data from the municipal wells are summarized in Table 3-5.

### 3.2 Perchlorate

$\text{ClO}_4^-$  analyses were conducted on groundwater samples from the April - May 2004 event using ion chromatography modified EPA Method 314.0 and the results are summarized in Table 3-3.  $\text{ClO}_4^-$  is among the unregulated chemicals requiring monitoring (Title 22, California Code of Regulations §64450). Although, no MCL has been established for  $\text{ClO}_4^-$ , the DHS has implemented an interim action level (IAL) to protect the public from the adverse health effects of  $\text{ClO}_4^-$ . On March 11, 2004, DHS revised its perchlorate IAL to 6  $\mu\text{g/L}$  (from the previous 4  $\mu\text{g/L}$ ). To protect consumers until an MCL is in place, DHS will use a 6  $\mu\text{g/L}$  action level (DHS, 2004c).

Concentrations of  $\text{ClO}_4^-$  in excess of the State IAL (6.0  $\mu\text{g/L}$ ) were reported in samples from seven on-facility wells [MW-3 (Screen 2), MW-7, MW-10, MW-13, MW-14 (Screens 1, 3, and 4), MW-16, and MW-24 (Screens 1 and 2)] and two off-facility wells [MW-17 (Screen 2) and MW-18 (Screen 4)].

The highest levels of  $\text{ClO}_4^-$  were reported in samples from MW-7 (4,680  $\mu\text{g/L}$ ), MW-16 (929  $\mu\text{g/L}$ ), and MW-24 (2,240  $\mu\text{g/L}$  in Screen 1). The maximum  $\text{ClO}_4^-$  concentration detected decreased significantly in MW-7 from 7,690  $\mu\text{g/L}$  in February 2004 to 4,680  $\mu\text{g/L}$  in April - May 2004.  $\text{ClO}_4^-$  concentrations have been contoured on Figures 3-10, 3-11, and 3-12 for aquifer layers 1, 2, and 3, respectively.

Additional data regarding  $\text{ClO}_4^-$  concentrations in samples collected from April 1, 2004 to June 30, 2004 from fourteen municipal production wells in the vicinity of JPL were requested from the DHS Drinking Water Program. However, according to DHS, only five of the fourteen municipal wells in the vicinity of JPL were sampled for  $\text{ClO}_4^-$  during the time period requested (DHS, 2004b). In summary,  $\text{ClO}_4^-$  exceeded the State IAL (6.0  $\mu\text{g/L}$ ) in LAWC Well #3 and Well #5, with a maximum concentration of 14.0  $\mu\text{g/L}$  in each of the two wells (DHS, 2004b).

### 3.3 Metals

Groundwater samples collected during the April - May 2004 event were analyzed for the following metals: arsenic, lead, Cr(VI), and Cr. The results of the metals analyses are presented in Table 3-6, and are summarized below.

- Arsenic was detected, at estimated concentrations, in two off-facility wells, MW-17 (Screens 3, 4, and 5) and MW-20 (Screen 3). The maximum concentration reported was 12.0  $\mu\text{g/L}$  in MW-17 (Screen 5). None of the results exceeded the State and Federal MCL for arsenic (50  $\mu\text{g/L}$ ).

- Lead was detected in twelve on-facility and three off-facility wells. The IAL (15.0 µg/L) was exceeded only in off-facility well MW-17 (73.3 µg/L in Screen 5).
- Cr(VI) was detected at estimated concentrations below the detection limit in five on-facility wells. The maximum concentration was reported in MW-4 (Screen 1) at 0.006 J milligrams per liter (mg/L). As of January 6, 2004, Cr(VI) is regulated under the 0.050 mg/L MCL for Cr. The DHS will be adopting an MCL that is specific for Cr(VI) at a later date (DHS, 2004a).
- Cr was detected in all 23 wells sampled during this monitoring event. However, the State MCL (50.0 µg/L) was not exceeded in any well. The maximum concentration of Cr was reported in MW-13 (31.5 µg/L).

Table 3-7 presents a summary of metals data from all quarterly sampling events completed to date during the long-term monitoring program.

### **3.4 1,4-Dioxane and NDMA**

During the April - May 2004 event, groundwater samples from five wells [MW-4 (Screen 1), MW-13, MW-16, MW-17 (Screen 4), and MW-24 (Screen 1)] were analyzed for 1,4-dioxane using EPA Method 8270 and for NDMA using modified EPA Method 1625. Samples from these five wells have historically contained the highest-reported concentrations of VOCs at JPL.

1,4-Dioxane was detected and reported at concentrations above the current drinking water IAL (3.0 µg/L) in on-site wells MW-13 (5.3 µg/L), MW-16 (3.1 µg/L) and MW-24 (3.2 µg/L in Screen 1). At this time, neither State nor Federal MCLs have been established for 1,4-dioxane.

NDMA was reported at a very low concentration in one groundwater sample, MW-24 (Screen 1) (0.000511 J µg/L). This result did not exceed the State IAL (0.01 µg/L). No State or Federal MCLs have been established for NDMA. The results for 1,4-dioxane and NDMA are presented in Table 3-8.

### **3.5 Quality Assurance/Quality Control**

Review of the QA/QC data provided with the laboratory analytical results indicates that all of the analytical results obtained from April - May 2004 samples are acceptable for their intended use of characterizing aquifer quality. Surrogate compound, matrix and blank spike, and method blank results were used by the laboratory to determine the accuracy and precision of the analytical techniques with respect to the JPL groundwater matrix, and to identify anomalous results due to laboratory contamination or instrument malfunction. In addition to laboratory QA/QC samples, GEOFON personnel collected QA/QC samples in the field in general

accordance with the Quality Assurance Project Plan (QAPP) (Ebasco, 1993c). The field QA/QC samples included duplicate samples, equipment rinsate blanks, and trip blanks.

Duplicate samples were used to evaluate the precision of the laboratory analyses. Duplicate samples for VOCs, metals, NDMA and/or  $\text{ClO}_4^-$  analyses were collected from monitoring wells MW-3 (Screen 1), MW-4 (Screen 2), MW-7, MW-11 (Screen 3), MW-12 (Screen 4), MW-15, and MW-22 (Screen 5).

All of the analytical results for the duplicate samples were comparable to the results of the original groundwater samples (Tables 3-3, 3-6, and 3-8).

Equipment rinsate blanks were collected each day non-dedicated sampling equipment was used. The equipment rinsate blanks, consisting of distilled water run through the sampling equipment after decontamination, were analyzed for all contaminants of concern to monitor possible cross-contamination of samples due to inadequate decontamination. Cr(VI) was detected at an estimated concentration below the practical quantitation limit (PQL) of the laboratory in one equipment blank. Cr, lead, and m,p-xylenes were detected at low concentrations in three equipment blanks. A laboratory-prepared trip blank, consisting of reagent-grade water placed in a vial and transported with the sample bottles to the field, was submitted to the laboratory with each daily shipment of groundwater samples. Trip blanks were used to help identify cross-contamination of groundwater samples during transport and/or deficiencies in the laboratory bottle cleaning and sample handling procedures. No contaminants were detected in any trip blank during the April - May 2004 sampling event. Table 3-9 presents a summary of contaminants detected in quality control samples collected during the April - May 2004 sampling event.

## 4.0 GENERAL WATER CHEMISTRY

As part of this groundwater monitoring event, groundwater samples were analyzed for major cations and anions in an effort to further understand the natural water chemistry of the groundwater beneath and adjacent to JPL. All groundwater samples collected during the April - May 2004 event were analyzed for major cations ( $\text{Ca}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ , and  $\text{K}^+$ ), major anions ( $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{CO}_3^{2-}$  and  $\text{HCO}_3^-$ ), pH, alkalinity, and total dissolved solids (TDS). The water chemistry results for this quarterly sampling event are summarized in Table 4-1.

### 4.1 Analytical Results

To illustrate the relative proportions of the major cations and anions in each groundwater sample, the water chemistry results from the April - May 2004 event have been plotted as Stiff diagrams (Figures 4-1, 4-2, and 4-3). Based on previous review of the water chemistry data, groundwater at JPL has been divided into three general types, based on the predominant cation and anion, and the occurrence of other ions. These general water types include:

- Type 1. Calcium-bicarbonate groundwater. Groundwater with  $\text{Ca}^{2+}$  as the dominant cation and  $\text{HCO}_3^-$  as the dominant anion.
- Type 2. Sodium-bicarbonate groundwater. Groundwater with  $\text{Na}^+$  as the dominant cation and  $\text{HCO}_3^-$  as the dominant anion.
- Type 3. Calcium-bicarbonate/chloride/sulfate groundwater. Groundwater with  $\text{Ca}^{2+}$  as the dominant cation and  $\text{HCO}_3^-$  as the dominant anion, but with relatively elevated  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  concentrations.

In addition to the general water types, the previous analytical data suggest that these water types mix or blend with one another, creating “intermediate” water types. For example, water Types 1 and 2 can mix to create a 1+2 or a 2+1 type, where the first number indicates the general water type that is predominant in the mixture. The Stiff diagrams presented in Figures 4-1 through 4-3 contain some graphical representations of these “intermediate” water types.

Water Type 1, the calcium-bicarbonate water type, was found to be the most common water type at JPL during the April - May 2004 sampling event. In general, it was found at relatively shallow depths in wells located around the Arroyo Seco, including MW-3, MW-17, and MW-18. Water Type 2, the sodium-bicarbonate water type (including associated blends) was typically found in the deeper well screens of both the on-site and off-site multi-port wells. Type 3 groundwater, the calcium-bicarbonate/chloride/sulfate water type, was prevalent in the shallower

screens of the monitoring wells located upgradient and to the south of the JPL facility. A list of water types and JPL monitoring wells in which they occur is provided in Table 4-2.

## **4.2 Quality Assurance/Quality Control**

To evaluate the general quality of the water chemistry data, two independent geochemical quality control checks of the analytical results from the April - May 2004 samples were performed. These checks included calculation of total ion-charge balances, and comparison of errors in the measured TDS values or the presence of other cations/anions. The results of these checks for this groundwater sampling event are presented in Table 4-3.

Charge balances are expressed as the percent difference between the sum of the equivalent weights of all of the anions and cations analyzed (Freeze and Cherry, 1979). The ideal range for charge balances is  $\pm 5$  percent, although charge balance errors up to  $\pm 10$  percent are considered acceptable. The charge balances for thirteen (13) of the 75 samples analyzed for major anions and cations during this sampling event are within the ideal range ( $\pm 5$  percent) for all wells. Thirty-eight (38) of the samples had charge balances between 5 and 10 percent, and twenty-four (24) samples had a charge balance over 10 percent. This indicates that 68% of the results are acceptable for their intended use.

TDS results were used to verify that all of the important water chemistry constituents were analyzed by comparing the measured laboratory TDS value to a calculated TDS value (calculated as the sum of the major anion and cation concentrations) for each sample. Under ideal conditions, the ratio of the measured to calculated TDS values should range from 0.8 to 1.2 (Oppenheimer and Eaton, 1986). The ratio of measured to calculated TDS values for the April - May 2004 water chemistry results fell within the ideal range (0.8 to 1.2) for 67 of the 75 sets of water chemistry analyses performed (Table 4-3). The TDS ratios for the remaining 11 sets of data fell outside this ideal range, which suggests possible minor analytical errors and/or the presence of other cations/anions. However, all of the data are considered suitable for their intended use of identifying differences in water chemistry across the site.

## **5.0 DATA VERIFICATION AND VALIDATION**

The purpose of data verification and validation is to assure that the data collected meet the data quality objectives (DQOs) outlined in the Quality Assurance Project Plan of the Groundwater Monitoring Plan (Ebasco, 1993c). The process is intended to ensure that the data are of sufficient quality for use in meeting the objectives outlined in the Groundwater Monitoring Plan.

### **5.1 Data Verification**

All data collected were subjected to data verification. In general, verification identifies non-technical errors in the data package that can be corrected (e.g., typographical errors). Data verification included proofreading and editing hard-copy data reports to assure that data correctly represent the analytical measurement. Data verification also included verifying that the sample identifiers on laboratory reports (hard copy) matched those on the chain-of-custody record.

### **5.2 Data Validation**

Data validation is a systematic process that is used to interpret, define, and document analytical data quality and determine whether the data quality is sufficient to support the intended use(s) of the data. Validation of a data package includes reconstruction of sample preparation, analysis of the raw data, reconciliation of the raw data with the reduced results, identification of data anomalies, and qualification of data to identify data usability limitations.

Data validation was performed by an independent subcontractor, Laboratory Data Consultants, Inc. (LDC), Carlsbad, CA. One hundred percent of all data analyzed by a fixed-base analytical laboratory (APCL) were validated. Ten percent of the data were subjected to Level IV quality assurance requirements of the Navy (Navy, 1996 and Navy, 1999). The data were further evaluated to help ensure suitability and usability for the purpose of the groundwater monitoring report.

### **5.3 Data Validation Qualifiers**

Analytical data were qualified based on data validation reviews. For chemical data, qualifiers were assigned in accordance with the applicable EPA National Functional Guidelines for Data Validation (EPA, 1994a and 1994b). Individual laboratory data flags can be found in Appendix D. No data were rejected for non-compliance with method requirements during the course of validation.



## **6.0 WATER LEVEL MEASUREMENTS**

Water level measurements were recorded before the sampling event on April 26 & 29, 2004 and after the sampling event on May 26 & 27, 2004 to evaluate groundwater flow directions and gradients beneath and adjacent to JPL. Water levels in the shallow wells were measured using a Solinst® water level meter. In the deep multi-port wells, the hydraulic head at each sampling port was measured with a Westbay pressure-transducer probe.

Water table elevation measurements taken before sampling are provided in Table 6-1 and have been contoured on Figure 6-1. Water table elevation measurements taken after sampling are provided in Table 6-2 and have been contoured on Figure 6-2. Piezometric pressure readings from the deep multi-port wells are generally recorded at the first screen interval. However, the recorded pressure readings from other screen intervals are used to validate the accuracy of the reading instrument or to screen for an erroneous field measurement at the first screen. Occasionally, the piezometric readings are determined to be out of range, when compared to the readings from the underlying screens. This could be attributed to several factors such as false readings or instrument errors. In either case, the piezometric pressure data that are deemed not usable are rejected and data from the underlying screens are used in the calculation of the water table elevation.

The hydraulic heads measured at each deep multi-port well screen before and after sampling are presented graphically on Figure 6-3. The piezometric pressure-profile records for the deep wells are included in Appendix B.

From April 26 to May 27, 2004, water levels in the shallow wells and in Aquifer Layer 1 decreased an average of about 3.3 feet, ranging from 0.2 feet to 8.8 feet. Water levels in Aquifer Layer 2 decreased an average of about 3.8 feet, ranging from 1.6 feet to 8.7 feet. Water levels in Aquifer Layer 3 decreased an average of about 4.2 feet, ranging from 1.6 feet to 17.2 feet. The only well screen in Aquifer Layer 4 (MW-20 Screen 5) showed a decrease of about 1.1 feet. Water levels in all aquifer layers generally decreased during this event.

Water level fluctuations can result from a wide variety of hydrologic phenomena, some natural and some induced by man. It is likely that several of these phenomena are operating simultaneously including, but not limited to:

- Groundwater recharge/infiltration to the water table,
- Air entrapment during groundwater recharge,
- Groundwater extraction, and/or
- Artificial recharge from the spreading grounds.

As depicted on Figures 6-1 and 6-2, the estimated groundwater flow direction both before and after sampling was generally consistent with previous observations. The flow was primarily to the south-southwest through the eastern portion of JPL and to the east-southeast in the southwest portion of JPL, Arroyo, and plain. The estimated groundwater gradients measured both at the beginning and end of the event ranged from about 0.20 feet per foot near MW-9, at the northern end of the Arroyo, to 0.005 feet per foot across the Arroyo and plain.

## 7.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based upon interpretation of analytical data and field measurements collected during the April - May 2004 event and previous events of the JPL Monitoring Program:

- The chemical plumes beneath JPL are adequately defined and relatively stable. The concentration contour maps generally indicate slow migration of the contaminant plumes over the last year. Comparison of the April - May 2004 results with the previous monitoring events showed some significant changes in contaminant concentrations including  $\text{ClO}^4$  at wells MW-7, MW-16, and MW-24 (Screen 1) and lead at MW-17 (Screen 5). In summary, the April - May 2004 analytical results indicate the following:
  - ◆ Four VOCs ( $\text{CCl}_4$ , TCE, PCE, and 1,1-DCE) were detected in one or more monitoring wells at concentrations above the State or Federal MCLs for drinking water. There were no significant increases or decreases in VOC concentrations from the previous event to the April - May 2004 event.
  - ◆  $\text{ClO}^4$  concentrations exceeded the State IAL for drinking water in seven on-facility wells and two off-facility wells. The highest levels and most significant changes in  $\text{ClO}^4$  concentrations were reported in samples from MW-7, MW-16, and MW-24 (Screen 1).  $\text{ClO}^4$  concentrations decreased at MW-7 and MW-16 from 7,690  $\mu\text{g/L}$  and 1,630  $\mu\text{g/L}$  in February 2004 to 4,680  $\mu\text{g/L}$  and 929  $\mu\text{g/L}$ , respectively, in April - May 2004. However,  $\text{ClO}^4$  concentrations doubled at MW-24 (Screen 1) from 1,120  $\mu\text{g/L}$  in February 2004 to 2,240  $\mu\text{g/L}$  in April - May 2004.
  - ◆ Cr(VI) was detected in five on-facility wells at estimated concentrations below the detection limit. Cr(VI) is currently regulated under the 0.050 mg/L MCL for Cr. The DHS will be adopting an MCL that is specific for Cr(VI) (DHS, 2004a). None of the Cr concentrations reported during the April - May event exceeded this regulatory standard.
  - ◆ Cr was detected in all 23 wells sampled; however, none of the concentrations exceeded the State or Federal MCL. Cr concentrations at MW-16 were previously reported above the State MCL in February 2004.

- ◆ Arsenic was detected, at estimated concentrations, only in two off-facility wells, MW-17 (Screens 3, 4, and 5) and MW-20 (Screen 3). None of the results exceeded the State and Federal MCL for arsenic (50 µg/L).
- ◆ Lead was detected in twelve on-facility and three off-facility wells. From April - May 2003 to April - May 2004, the concentration of lead at MW-17 (Screen 5) increased from 0.6 µg/L to 73.3 µg/L. This result exceeded the State IAL (15 µg/L) and is the highest reported concentration of lead since the groundwater monitoring program began at JPL in August 1996.
- ◆ 1,4-Dioxane was detected and reported at concentrations slightly above the current drinking water IAL (3.0 µg/L) in three on-site wells. At this time, neither State nor Federal MCLs have been established for 1,4-dioxane.
- ◆ NDMA was reported in MW-24 (Screen 1) below State IAL (0.01 µg/L). No State or Federal MCLs have been established for NDMA.
- ◆ Changes in specific monitoring well groundwater concentrations that were significant in relation to the previous quarter's concentrations include a reduction of CC1<sub>4</sub> and ClO<sup>4-</sup> in MW-8 to below MCL and IAL, an increase in CC1<sub>4</sub> and ClO<sup>4-</sup> in MW-10 to above MCL and IAL, an increase in ClO<sup>4-</sup> to above the IAL in MW-14 (Screen 4), a reduction of ClO<sup>4-</sup> in MW-17 (Screen 3) from 162 µg/L to non-detect, and a reduction of PCE to below MCL in MW-21 (Screen 4).
- ◆ Moderate decreases in hydraulic head were measured during this event in shallow wells and Westbay well screens in all Aquifer Layers (1, 2, 3, and 4). The water level fluctuations are likely due to several hydrologic phenomena operating simultaneously including, but not limited to, groundwater recharge, pumpage, and/or artificial recharge.
- ◆ Groundwater gradient maps prepared using the April - May 2004 water level measurements indicate that groundwater gradients and flow directions are generally consistent with previous observations (GEOFON, 2004, SOTA, 2002, 2001 and Foster Wheeler, 2000).

GEOFON recommends that the Groundwater Monitoring program be continued at the site. The next quarterly event is scheduled to be performed during August 2004.

## 8.0 REFERENCES

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